Spread-spectrum system and meth d

Patent number: EP1041727
Publication date: 2000-10-04
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Classification:
- international: H04B1/707
- european: H04B7/005B2H; H04B1/707F3
Application number: EP20000114939 19951222
Priority number(s): EP19950943981 19951222; US19950368710 19950104

Also publishe
EP104
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Cited docum
US530
WO94
WO94

Abstract of **EP1041727**

A spread-spectrum system and method for providing high-capacity communications through multipath compensation, for automatically and adaptively controlling a mobile user's spread-spectrum transmitter power level when operating in a cellular communications network, and for providing variable or adjustable signal bandwidth capabilities in a spread spectrum transmitter. Multipath compensation is accomplished using a plurality of filters 121-126, a plurality of multipliers 111-116, and a plurality of weighting devices 131-136, coupled through a first adder 120 and a second adder 130 to a decision device 150. The adaptive power control device of the present invention includes a base station having an AGC amplifier 228, despreader 231, comparator 239, power amplifier 237, delta modulator 235, multiplexer 234, combiner 236 and power measurement device 233. The adaptive power control device also includes a mobile station having a despreader 334, demultiplexer 339, demodulator 340, decision device 345, accumulator 346, step size algorithm device 344, variable gain device 341 and transmitter 342. The variable bandwidth device includes a chipping sequence generator 161, impulse generator 165, product device 164 and filter 166.

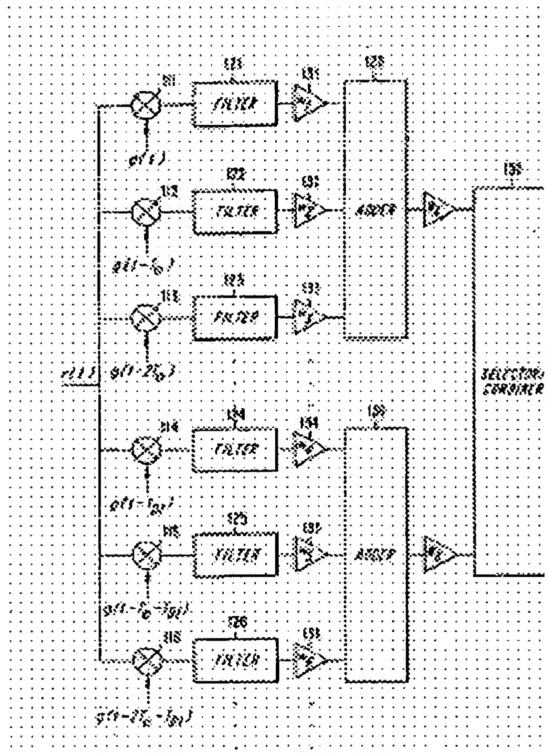

FIG. 3

Spread-spectrum system and meth d

Description of **EP1041727**

BACKGROUND OF THE INVENTION

[0001] This invention relates to spread-spectrum communications, and more particularly to a multipath proces variable bandwidth device, and power control system.

DESCRIPTION OF THE RELEVANT ART

[0002] Spread-spectrum modulation provides means for communicating in which a spread-spectrum signal oc a bandwidth in excess of the minimum bandwidth necessary to send the same information. The band spread accomplished by modulating an information-data signal with a chipping-sequence signal which is independen information-data signal. The information-data signal may come from a data device such as a computer, or an device which outputs an analog signal which has been digitized to an information-data signal, such as voice c video. The chipping-sequence signal is generated by a chip-code where the time duration, Tc, of each chip is substantially less than a data bit or data symbol. A synchronized reception of the information-data signal with chipping-sequence signal at a receiver is used for despreading the spread-spectrum signal and subsequent r of data from the spread-spectrum signal.

[0003] Spread-spectrum modulation offers many advantages as a communications system for an office or urt environment. These advantages include reducing intentional and unintentional interference, combating multip problems, and providing multiple access to a communications system shared by multiple users. Commerciall applications include, but are not limited to, local area networks for computers and personal communications networks for telephone, as well as other data applications.

[0004] A cellular communications network, using spread-spectrum modulation for communicating between a l station and a multiplicity of users, requires control of the power level of a particular mobile user station. Withir particular cell, a mobile station near the base station of the cell may be required to transmit with a power leve than that required when the mobile station is near an outer perimeter of the cell. This adjustment in power lev done to ensure a constant power level is received at the base station from each mobile station.

[0005] In a first geographical region, such as an urban environment, the cellular architecture may have small which the respective base stations are close to each other, requiring a low power level from each mobile user second geographical region, such as a rural environment, the cellular architecture may have large cells in whi respective base stations are spread apart, requiring a relatively high power level from each mobile user. A mc user who moves from the first geographical region to the second geographical region typically adjusts the pov level of his transmitter in order to meet the requirements of a particular geographic region. If such adjustment not made, a mobile user traveling from a sparsely populated region with larger cells, using the relatively highe power level with his spread-spectrum transmitter, to a densely populated region with many small cells may, w reducing the original power level of his spread-spectrum transmitter, cause undesirable interference within th smaller cell into which he has traveled and/or to adjacent cells. Also, if a mobile user moves behind a building has his signal to the base station blocked by the building, then the mobile user's power level should be increa These adjustments must be made quickly, with high dynamic range and in a manner to ensure an almost con received power level with low root mean square error and peak deviations from the constant level.

[0006] Accordingly, there is a need to have a spread-spectrum system and method for automatically controllir mobile user's spread-spectrum transmitter power level when operating in a cellular communications network.

SUMMARY OF THE INVENTION

[0007] A general object of the invention is high capacity communications, due to lower multipath fading and tc equivalent bandwidth and data rate.

[0008] A second general object of the invention is a spread spectrum transmitter having variable and/or adjus

signal bandwidth capabilities.

[0009] Another general object of the invention is a system and method which results in maximization of user c within a cell domain while minimizing mobile user transmitted power.

[0010] A further object of the invention is to provide an apparatus and method which controls the power level mobile station so that the power level received at the base station of each cell is the same for each mobile sta

[0011] Another object of the invention is to provide a system and method for automatically and adaptively con the power level of a mobile user in a cellular communications network.

[0012] A further object of the invention is to provide a spread-spectrum system and method which allows ope spread-spectrum transmitter in different geographic regions, wherein each geographic region has a multiplicit cells, and wherein cells within a geographic region may have different size cells and transmitter power require

[0013] In a multipath environment, a spread spectrum signal reflects from multiple surfaces, such as buildings assumed to generate a multiplicity of spread-spectrum signals. The multiplicity of spread-spectrum signals typ appear in a plurality of groups of spread-spectrum signals, with each group of spread-spectrum signals having plurality of spread-spectrum signals. The plurality of groups of spread-spectrum signals are a result of the spr spectrum signal reflecting in a multipath environment.

[0014] A multipath processor for tracking a spread-spectrum signal arriving in a plurality of groups is provided multipath processor includes a first plurality of correlators, a second plurality of correlators, a first adder, a sec adder, and a selector device or a combiner device. The first adder is coupled between the first plurality of corr and the selector device or the combiner device. The second adder is coupled between the second plurality of correlators and the selector device or the combiner device.

[0015] The first plurality of correlators despreads a first plurality of spread-spectrum signals within a first grou generate a first plurality of despread signals. The first adder adds or combines the first plurality of despread s to generate a first combined-despread signal.

[0016] The second plurality of correlators despreads a second plurality of spread-spectrum signals within a se group to generate a second plurality of despread signals. The second adder adds or combines the second plu of despread signals to generate a second combined-despread signal.

[0017] The selector device selects either the first combined-despread signal or the second combined-despre signal. The selected combined-despread signal is outputted from the decision device as an output-despread s Alternatively, the combiner device may combine or add the first combined-despread signal with the second combined-despread signal to generate the output-despread signal.

[0018] The present invention also includes a variable-bandwidth spread-spectrum device for use with a sprea spectrum transmitter. The variable-bandwidth spread-spectrum device generates a spread-spectrum signal h spread bandwidth. The variable-bandwidth spread-spectrum device uses a chipping-sequence signal having chipping rate, with the chipping rate being less than the spread bandwidth.

[0019] The variable-bandwidth spread-spectrum device includes a chipping-sequence generator, spread-spe processing means, an impulse generator, and a filter. The spread-spectrum processing means is coupled to t chipping-sequence generator. The impulse generator is coupled to the spread-spectrum processing means. T filter is coupled to the impulse generator.

[0020] The chipping-sequence generator generates the chipping-sequence signal with the chipping rate. The spread-spectrum processing means processes a data signal with the chipping-sequence signal to generate a spread-data signal. The impulse generator, responsive to each chip in the spread-data signal, generates an i signal. The filter filters a spectrum of each impulse signal with the spread bandwidth.

[0021] The spread-spectrum processing means may be embodied as an EXCLUSIVE-OR gate, a product dev other device as is well known in the art for spread-spectrum processing data signals with chipping-sequence s The filter may include a variable bandwidth filter. The variable bandwidth filter may be used for varying or adju the spread bandwidth of the spectrum for each impulse signal. Accordingly, a spread-spectrum signal may be designed having the bandwidth of choice, based on the bandwidth of the variable-bandwidth filter. The bandw may be variable, or adjustable, as would be required for particular system requirements. As used in this pater variable bandwidth is one that is able to vary according to time conditions or other requirements in a particula system. An adjustable bandwidth would be similar to a variable bandwidth, but is used to refer to a bandwidth

may be adjusted to remain at a chosen setting.

[0022] A system for adaptive-power control (APC) of a spread-spectrum transmitter is also provided. A plurali mobile stations operate in a cellular-communications network using spread-spectrum modulation. A mobile st transmits a first spread-spectrum signal. The base station transmits a second spread-spectrum signal.

[0023] The base station includes automatic gain control (AGC) means, base-correlator means, comparator m power means, transmitter means, and an antenna. The base-correlator means is coupled to the AGC means. power means is coupled to the base-correlator means and to the comparator means. The comparator means coupled to the power means. The antenna is coupled to the transmitter means.

[0024] Each mobile station includes despreading means and variable-gain means.

[0025] A received signal is defined herein to include the first spread-spectrum signal and an interfering signal. interfering signal is defined herein to include noise and/or other spread-spectrum signals and/or other undesi signals which are coexistent in frequency with the first spread-spectrum signal.

[0026] For each received signal, the AGC means generates an AGC-output signal. The base-correlator mean despreads the AGC-output signal. The power means processes the despread-AGC-output signal and genera received-power level. The comparator means generates a power-command signal by comparing the received level to a threshold level. The power-command signal may be an analog or digital data signal, or a data signa multiplexed with information data bits. The transmitter means at the base station transmits the power-comma signal as the second spread-spectrum signal or as a data signal multiplexed with the information data bits.

[0027] At each mobile station, the despreading means despreads the power-command signal from the secon spread-spectrum signal as a power-adjust signal. The variable-gain means uses the power-adjust signal as a for adjusting a transmitter-power level of the first spread-spectrum signal transmitted from the mobile-station transmitter. The transmitter-power level may be adjusted linearly or nonlinearly.

[0028] The present invention also includes a method for automatic-power control of a spread-spectrum transr for a mobile station operating in a cellular-communications network using spread-spectrum modulation. A mo station transmits a first spread-spectrum signal. The base station performs the steps of acquiring the first spre spectrum signal transmitted from the mobile station, and detecting a received power level of the first spread-spectrum signal plus any interfering signal including noise. The steps also include generating an AGC-output from the received signal, and despreading the AGC-output signal. The despread AGC-output signal is proces generate a received-power level. The method further includes comparing the received-power level to the thre level to generate a power-command signal. The power-command signal is transmitted from the base station a of the second spread-spectrum signal.

[0029] At the mobile station the method despreads the power-command signal from the second spread-spect signal, and adjusts a transmitter power level of the first spread-spectrum signal in response to the power-com signal.

[0030] Additional objects and advantages of the invention are set forth in part in the description which follows, part are obvious from the description, or may be learned by practice of the invention. The objects and advant the invention also may be realized and attained by means of the instrumentalities and combinations particula pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The accompanying drawings, which are incorporated in and constitute a part of the specification, illust preferred embodiments of the invention, and together with the description serve to explain the principles of th invention.

FIG. 1 illustrates channel impulse response giving rise to several multipath signals;
FIG. 2 illustrates conditions leading to two groups of several multipath signals;
FIG. 3 is a block diagram of a multipath processor using two sets of correlators for despreading a spread-spe signal received as two groups of spread-spectrum signals;
FIG. 4 is a block diagram for generating chipping-sequence signals with delays;
FIG. 5 is a tapped-delay line model of a communications channel;
FIG. 6 is a block diagram of a correlator;
FIG. 7 is an auto correlation function diagram generated from the correlator of FIG. 6;

FIG. 8 is a block diagram for tracking a received signal;
FIG. 9 is a block diagram for combining a pilot signal from a received spread-spectrum signal;
FIG. 10 is a block diagram for tracking a pilot signal embedded in a pilot channel of a spread-spectrum signal
FIG. 11 illustrates cross-correlation between a received signal and a referenced chipping-sequence signal, as function of referenced delay;
FIG. 12 illustrates the center of gravity of the cross-correlation function of FIG. 11;
FIG. 13 is a block diagram of a multipath processor using two sets of matched filters for despreading a spread spectrum signal received as two groups of spread-spectrum signals;
FIG. 14 is a block diagram of a multipath processor using three sets of correlators for despreading a spread-spectrum signal received as three groups of spread-spectrum signals;
FIG. 15 is a block diagram of a multipath processor using three matched filters for despreading a spread-spec signal received as three groups of spread-spectrum signals;
FIG. 16 is a block diagram of a variable-bandwidth spread-spectrum device;
FIG. 17 illustrates chips of a spread-data signal;
FIG. 18 illustrates impulse signals corresponding to the chips of the spread-data signal of FIG. 17;
FIG. 19 is an alternative block diagram of the variable-bandwidth spread-spectrum device of FIG. 16;
FIG. 20 is a block diagram of a base station;
FIG. 21 is a block diagram of a mobile station;
FIG. 22 illustrates nonlinear power adjustment;
FIG. 23 illustrates linear and nonlinear power adjustment;
FIG. 24 illustrates fades during transmission for multiple signals of equivalent power received at a base statio
FIG. 25 illustrates an adaptive power control signal of broadcast power for a fixed step algorithm;
FIG. 26 illustrates despread output power for a fixed step algorithm;
FIG. 27 illustrates an adaptive power control signal of broadcast power for a variable step algorithm; and
FIG. 28 illustrates despread output power for a variable step algorithm.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] Reference now is made in detail to the present preferred embodiments of the invention, examples of w are illustrated in the accompanying drawings, wherein like reference numerals indicate like elements through several views.

Multipath Processor

[0033] In a multipath environment, a signal reflects from several buildings or other structures. The multiple ref from the several buildings can result in several signals, or several groups of signals, arriving at a receiver. FIC illustrates a signal arriving in time as several signals. FIG. 2 illustrates a signal arriving in time as two groups several signals. The multiple signals arriving at the receiver usually do not arrive with a uniform spread over ti Thus, in a multipath environment, a received signal r(t) may include two or more groups of spread-spectrum s

[0034] In the multipath environment, a spread-spectrum signal is assumed to generate a plurality of groups of spread-spectrum signals, with each group having a plurality of spread-spectrum signals. The plurality of grou the result of the spread-spectrum signal reflecting in a multipath environment. As a means of responding to a dealing with this plurality of groups, the multipath processor is an improvement to a spread-spectrum receiver system.

[0035] In the exemplary arrangement shown in FIG. 3, a multipath processor for tracking a spread-spectrum s shown. The multipath processor is used as part of a spread-spectrum receiver system.

[0036] The multipath processor includes first despreading means, second despreading means, first combining means, second combining means, and selecting means or output-combining means. The first combining mea coupled between the first despreading means and the selecting means or the output-combining signal. The s combining means is coupled between the second despreading means and the selecting means or the output-combining means.

[0037] The first despreading means despreads a received signal having a first plurality of spread-spectrum si within a first group. The first despreading means thus generates a first plurality of despread signals. The first combining means combines, or adds together, the first plurality of despread signals to generate a first combin despread signal.

[0038] The second despreading means despreads the received signal having a second plurality of spread-sp signals within a second group. The second despreading means thereby generates a second plurality of despr signals. The second combining means combines, or adds together, the second plurality of despread signals a second combined-despread signal.

[0039] The selecting means selects either the first combined-despread signal or the second combined-despre signal. The selected combined-despread signal is outputted from the selecting means as an output-despread The selecting means may operate responsive to the stronger signal strength of the first combined-despread s and the second combined-despread signal, least mean square error, a maximum likelihood, or other selectior criteria. Alternatively, using output-combining means in place of selecting means, the outputs of the first comb means and the second combining means may be coherently combined or added together, after suitable weig

[0040] As shown in FIG. 3, the first despreading means may include a first plurality of correlators for despreac respectively, the first plurality of spread-spectrum signals. The first plurality of correlators is illustrated, by way example, as first multiplier 111, second multiplier 112, third multiplier 113, first filter 121, second filter 122, thi 123, first chipping-sequence signal g(t), second chipping-sequence signal g(t-To), and third chipping-sequenc signal g(t-2To). The second chipping-sequence signal g(t-To) and the third chipping-sequence signal g(t-2To) the same as the first chipping-sequence signal g(t), but delayed by time To and time 2To, respectively. The d between each chipping-sequence signal, preferably, is a fixed delay To.

[0041] At the input is received signal r(t). The first multiplier 111 is coupled between the input and the first filte and to a source of the first chipping-sequence signal g(t). The second multiplier 112 is coupled between the ir and the second filter 122, and to a source of the second chipping-sequence signal g(t-To). The third multiplie coupled between the input and the third filter 123, and to a source of the third chipping-sequence signal g(t-2 The outputs of the first filter 121, the second filter 122 and the third filter 123 are coupled to the first adder 12

[0042] Circuitry and apparatus are well known in the art for generating chipping-sequence signals with variou delays. Referring to FIG. 4, a chipping-sequence generator 401 is coupled to a voltage-controlled oscillator 4 a plurality of delay devices 403, 404, 405, 406. The voltage-controlled oscillator receives a group-delay signa group-delay signal corresponds to the time delay that the group of chipping-sequence signals used for despre a particular group of received signals. The voltage-controlled oscillator 402 generates an oscillator signal. Th chipping-sequence generator 401 generates the first chipping-sequence signal g(t) from the oscillator signal, initial position of the first chipping-sequence signal g(t) determined from the group-delay signal. The first chip sequence signal g(t) is delayed by the plurality of delay devices 403, 404, 405, 406, to generate the second chipping-sequence signal g(t-To), the third chipping-sequence signal g(t-2To), the fourth chipping-sequence s (gt-3To), etc. Thus, the second chipping-sequence signal g(t-To) and the third chipping-sequence signal g(t-2 may be generated as delayed versions of the first chipping-sequence signal g(t). Additionally, acquisition and tracking circuitry are part of the receiver circuit for acquiring a particular chipping-sequence signal embedded received spread-spectrum signal.

[0043] Optionally, the multipath processor of FIG. 3 may include first weighting device 131, second weighting 132 and third weighting device 133. The first weighting device 131 is coupled to the output of the first filter 12 a source of a first weighting signal W1. The second weighting device 132 is coupled to the output of the seco 122, and to a source of the second weighting signal W2. The third weighting device 133 is coupled to the out the third filter 123 and to a source of the third weighting signal W3. The first weighting signal W1, the second weighting signal W2 and the third weighting signal W3 are optional, and may be preset within the first weighti device 131, the second weighting device 132 and the third weighting device 133, respectively. Alternatively, t weighting signal W1, the second weighting signal W2, and the third weighting signal W3 may be controlled by processor or other control circuitry. The outputs of the first filter 121, the second filter 122, and the third filter 1 coupled through the first weighting device 131, the second weighting device 132 and the third weighting devic respectively, to the first adder 120.

[0044] Similarly, the second despreading means may include a second plurality of correlators for despreading second plurality of spread-spectrum signals. The second plurality of correlators is illustrated, by way of examp fourth multiplier 114, fifth multiplier 115, sixth multiplier 116, fourth filter 124, fifth filter 125, sixth filter 126, fou chipping-sequence signal g(t-TD1), fifth chipping-sequence signal g(t-To-TD1), and sixth chipping-sequence (t-2To-TD1). The fourth multiplier 114 is coupled between the input and the fourth filter 124, and a source of t fourth chipping-sequence signal g(t-TD1). The fifth multiplier 115 is coupled between the input and the fifth fil and a source of the fifth chipping-sequence signal g(t-To-TD1). The sixth multiplier 116 is coupled between th and the sixth filter 126, and a source of the sixth chipping-sequence signal g(t-2To-TD1). The fourth chipping-sequence signal g(t-TD1), the fifth chipping-sequence signal g(t-To-TD1) and the sixth chipping-sequence sig 2To-TD1) are the same as the first chipping-sequence signal g(t), but delayed by time TD1, time To+TD1, an 2To+TD1, respectively. The second plurality of correlators thereby generates the second plurality of despreac

signals. The outputs of the fourth filter 124, the fifth filter 125 and the sixth filter 126 are coupled to the seconc 130.

[0045] At the output of the fourth filter 124, the fifth filter 125, and the sixth filter 126, optionally, may be fourth weighting device 134, fifth weighting device 135, and sixth weighting device 136. The fourth weighting device fifth weighting device 135, and sixth weighting device 136 are coupled to a source which generates fourth we signal W4, fifth weighting signal W5, and sixth weighting signal W6, respectively. The fourth weighting signal ' fifth weighting signal W5, and the sixth weighting signal W6 are optional, and may be preset within the fourth weighting device 134, the fifth weighting device 135, and the sixth weighting device 136, respectively. Alterna the fourth weighting signal W4, the fifth weighting signal W5, and the sixth weighting signal W6 may be contrc a processor or other control circuitry. The outputs of the fourth filter 124, fifth filter 125, and sixth filter 126 are coupled through the fourth weighting device 134, fifth weighting device, 135 and sixth weighting device 136, respectively, to the second adder 130. The output of the first adder 120 and the second adder 130 are couple the decision device 150. The decision device 150 may be a selector or a combiner.

[0046] The weighting devices may be embodied as an amplifier or attenuation circuits, which change the mag and phase. The amplifier or attenuation circuits may be implemented with analog devices or with digital circui amplifier circuit or attenuation circuit may be adjustable, with the gain of the amplifier circuit or attenuation circ controlled by the weighting signal. The use of a weighting signal with a particular weighting device is optional. particular weighting device may be designed with a fixed weight or a preset amount, such as a fixed amount (amplifier gain.

[0047] FIG. 5 is a tapped-delay-line model of a communications channel. A signal s(t) entering the communic channel passes through a plurality of delays 411, 412, 413, 414, modeled with time To. The signal s(t), for ea delay, is attenuated 416, 417, 418 by a plurality of complex attenuation factors h<n> and adder 419. The OU from the adder 419 is the output from the communications channel.

[0048] A given communications channel has a frequency response which is the Fourier transform of the impu response.
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where ai represents the complex gains of the multipaths of the communications channel, and tau i represents delays of the multipaths of the communications channel.

[0049] Consider the communications-channel-frequency response, Hc(f). The communications-channel-frequ response has a band of interest, B. Hereafter, this band of interest is fixed, and the communications-channel-frequency response Hc(f) is the equivalent lowpass filter function. The communications-channel-frequency re: expands in Fourier series as
Hc(f) = SIGMA hne<-jn2 pi f/B>
where hn represents Fourier coefficients. This is a tapped-delay-line model of the communications channel fo the receiver in FIG. 3 acts as a matched filter when To = 1/B, and the weights Wn are set to the complex conj of the values hn. That is, Wn = hn.

[0050] Preferably, each correlator of the first plurality of correlators despreads with a chipping-sequence sign: which has a time delay different from each time delay of each chipping-sequence signal used, respectively, w each of the other correlators of the first plurality of correlators. The first plurality of correlators uses chipping-sequence signals g(t), g(t-To), g(t-2To), where To is the time delay between chipping-sequence signals. The delay To may be the same or different between each chipping-sequence signal. For illustrative purposes, tim To is assumed to be the same.

[0051] Similarly, each correlator of the second plurality of correlators despreads with a chipping-sequence sig having a time delay different from each time delay of each other chipping-sequence signal used, respectively, each of the other correlators of the second plurality of correlators. Also, each correlator of the second pluralit correlators despreads with a chipping-sequence signal having the time delay TD1 different from each time de each chipping-sequence signal used with each respective correlator of the first plurality of correlators. Thus, t second plurality of correlators uses chipping-sequence signals g(t-TD1), g(t-To-TD1), g(t-2To-TD1), where tin delay TD1 is the time delay between the first plurality of correlators and the second plurality of correlators. Th delay TD1 is also approximately the same time delay as between the first received group of spread-spectrum and the second received group of spread-spectrum signals.

[0052] FIG. 6 illustrates a correlator, where an input signal s(t) is multiplied by multiplier 674 by a delayed ver: the input signal s(t-T). The product of the two signals is filtered by the filter 675, and the output is the autocor function R(T). The autocorrelation function R(T) for a square wave input signal s(t) is shown in FIG. 7. Over a time Tc, the correlation function R(T) is maximized when points A and B are equal in amplitude. A circuit whic well known in the art for performing this function is shown in FIG. 8. In FIG. 8, the despread signal s(t) is dela

a half chip time Tc/2, and forwarded by half a chip time Tc/2. Each of the three signals are multiplied by the re signal r(t). The outputs of the delayed and forwarded multiplied signals are filtered, and then amplitude detect two filtered signals are combined by subtracting the delayed version from the forwarded version, and the diffe or error signal is used to adjust the timing of the chipping-sequence signal used to despread signal s(t). Accoı if the delayed version were ahead of the forwarded version, the chipping-sequence signal for despread signal would be delayed. Likewise, if the forwarded version were ahead of the delayed version, then the chipping-se signal for despreading signal s(t) would be advanced. These techniques are well known in the art.

[0053] A similar technique is used for estimating a pilot signal from a received signal r(t), which has passed th a multipath environment. Referring to FIG. 9, the lower part of the diagram shows correlators corresponding t correlators previously shown in FIG. 3. The upper part of the diagram shows the received signal processed b delayed versions of the pilot chipping-sequence signal gp(t). In FIG. 9, the received signal r(t) is multiplied by pilot signal gp(t), and a plurality of delayed versions of the pilot signal gp(t-To), ..., gp(t-kTo) by a plurality of multipliers 661, 651, 641. The output of the plurality of multipliers 661, 651, 641, are each filtered by a pluralit filters 662, 652, 642, respectively. The output of the plurality of filters 662, 652, 642 are multiplied by a secon plurality of multipliers 663, 653, 643 and respectively filtered by a second plurality of filters 664, 654, 644. The outputs of the second plurality of filters 664, 654, 644 are processed through a plurality of complex conjugate devices 665, 655, 645. The outputs of the plurality of complex conjugate devices 665, 655, 645 are the plurali weights W1, W2, Wk, respectively. The plurality of weights are multiplied by the output of the first plurality of f 662, 652, 642, by a third plurality of multipliers 666, 656, 646, and then combined by the combiner 667. At the of the combiner 667 is a combined-despread-pilot signal.

[0054] Each of the second plurality of pilot filters 664, 654, 644 has a bandwidth which is approximately equal fading bandwidth. This bandwidth typically is very narrow, and may be on the order of several hundred Hertz.

[0055] Referring to FIG. 10, the output of the combiner 667 is multiplied by a fourth multiplier 668, and passe through an imaginary device 669 for determining the imaginary component of the complex signal from the fou multiplier 668. The output of the imaginary device 669 passes through a loop filter 672 to a voltage controlled oscillator 673 or a numerically controlled oscillator (NCO). The output of the voltage controlled oscillator 673 to the fourth multiplier 668 and to each of the second plurality of multipliers 663, 653, 643.

[0056] Referring to FIG. 11, the foregoing circuits can generate a cross-correlation function between the recei signal and a referenced pilot-chipping signal as a function of referenced delay, or lag. As shown in FIG. 11, th points of cross-correlation can have a center of gravity. The center of gravity is determined when the left mas equals the right mass of the correlation function, as shown in FIG. 12. A circuit similar to that shown in FIG. 8 coupled to the output of the fourth multiplier 668, can be used for aligning a chipping-sequence signal of the channel.

[0057] As an alternative embodiment, as shown in FIG. 13, the first despreading means may include a first pl of matched filters for despreading the received signal r(t) having the first plurality of spread-spectrum signals. output of the first plurality of matched filters is the first plurality of despread signals. Each matched filter of the plurality of matched filters has an impulse response h(t), h(t-To), h(t-2To), etc., with a time delay To offset fro other matched filters. Referring to FIG. 13, by way of example, a first matched filter 141 is coupled between t and through the first weighting device 131 to the first adder 120. A second matched filter 142 is coupled betw input and through the second weighting device 132 to the first adder 120. A third matched filter 143 is couple between the input and through the third weighting device 133 to the first adder 120. As mentioned previously, first weighting device 131, the second weighting device 132, and the third weighting device 133 are optional. first weighting device 131, the second weighting device 132, and the third weighting device 133 generally are connected to a source of the first weighting signal W1, the second weighting signal W2, and the third weightir signal W3, respectively. The first plurality of matched filters generates the first plurality of despread signals.

[0058] Similarly, the second despreading means may include a second plurality of matched filters for desprea the received signal r(t) having the second plurality of spread-spectrum signals. Accordingly, at the output of th second plurality of matched filters is the second plurality of despread signals. Each matched filter of the seco plurality of matched filters has an impulse response, h(t-TD1), h(t-To-TD1), h(t-2To-TD1), etc., with a time del offset from the other matched filters and with a time delay TD1 offset from the first plurality of matched filters. fourth matched filter 144 is coupled between the input and through the fourth weighting device 134 to the sec adder 130. A fifth matched filter 145 is coupled between the input, and through the fifth weighting device 135 second adder 130. A sixth matched filter 146 is coupled between the input and through the sixth weighting de 136 to the second adder 130. As mentioned previously, the fourth weighting device 134, the fifth weighting de 135, and the sixth weighting device 136 are optional. The fourth weighting device 134, the fifth weighting devi and the sixth weighting device 136, are coupled respectively to a source for generating the fourth weighting s W4, the fifth weighting signal W5, and the sixth weighting signal W6. Also, as with the correlator embodiment, first adder 120 and the second adder 130 are coupled to the decision device 150. The decision device 150 m

embodied as a selector or a combiner.

[0059] The present invention may further include despreading spread-spectrum signals located within a third ; Accordingly, the present invention may include third despreading means and third combining means. The thir combining means is coupled between the third despreading means and the selecting means.

[0060] As shown in FIG. 14, the third despreading means despreads the received signal r(t) received as a thi plurality of spread-spectrum signals within a third group. Accordingly, the third despreading means generates plurality of despread signals. The third combining means combines the third plurality of despread signals as a combined-despread signal. The selecting means selects one of the first combined-despread signal, the secor combined-despread signal or the third combined-despread signal. The output of the selecting means is the ou despread signal.

[0061] As shown in FIG. 14, the third despreading means may include a third plurality of correlators for despr the third plurality of spread-spectrum signals. The third plurality of correlators is illustrated, by way of example seventh multiplier 117, eighth multiplier 118, ninth multiplier 119, seventh filter 127, eighth filter 128, ninth filte and a source for generating the seventh chipping-sequence signal g(t-TD2), the eighth chipping-sequence sig To-TD2), and the ninth chipping-sequence signal g(t-2To-TD2). The seventh multiplier 117 is coupled betwee input and the seventh filter 127. The eighth multiplier 118 is coupled between the input and the eighth filter 12 ninth multiplier 119 is coupled between the input and the ninth filter 129. The seventh multiplier 117, the eight multiplier 118, and the ninth multiplier 119, are coupled to the source for generating the seventh chipping-seq signal, the eighth chipping-sequence signal and the ninth chipping-sequence signal, respectively. Optionally, output of the seventh filter 127, eighth filter 128, and ninth filter 129, may be seventh weighting device 137, ei weighting device 138, and ninth weighting device 139, respectively. Accordingly, the output of the seventh filt is coupled through the seventh weighting device 137 to the third adder 140. The output of the eighth filter 128 coupled through the eighth weighting device 138 to the third adder 140. The output of the ninth multiplier 129 coupled through the ninth weighting device 139 to the third adder 140. The third adder is coupled to the decis device 150. At the output of the third plurality of correlators is the third plurality of despread signals, respectiv

[0062] Preferably, each correlator of the third plurality of correlators despreads with a chipping-sequence sign TD2), g(t-To-TD2), g(t-2To-TD2) having a time delay To different from each time delay of each chipping-sequ signal used with other correlators of the third plurality of correlators. Also, each correlator of the third plurality correlators despreads with a chipping-sequence signal having a time delay different from each time delay of e chipping-sequence signal used, respectively, with each correlator of the second plurality of correlators. Also, correlator of the third plurality of correlators despreads with a chipping-sequence signal having a time delay 2 different from each chipping-sequence signal used with each correlator of the first plurality of correlators.

[0063] Alternatively, the third despreading means may include, as shown in FIG. 15, a third plurality of match filters for despreading the third plurality of spread-spectrum signals. The third plurality of matched filters inclu seventh matched filter 147, eighth matched filter 148, and ninth matched filter 149. The seventh matched filte coupled between the input and through the seventh weighting device 137 to the third adder 140. The eighth n filter 148 is coupled between the input and through the eighth weighting device 138 to the third adder 140. Th matched filter 149 is coupled between the input and through the ninth weighting device 139 to the third adder The third adder 140 is coupled to the decision device 150. At the output of the third plurality of matched filters third plurality of despread signals.

[0064] The present invention may include fourth despreading means and fourth combining means, with the fo combining means coupled between the fourth despreading means and the selecting means. The fourth despr means would despread a fourth plurality of spread-spectrum signals within a fourth group. The output of the f despreading means would be a fourth plurality of despread signals. The fourth combining means would comb fourth plurality of despread signals as a fourth combined-despread signal. The selecting means selects one o first combined-despread signal, the second combined-despread signal, the third combined-despread signal, c fourth combined-despread signal, as the output-despread signal.

[0065] In a similar fashion, the fourth despreading means includes a fourth plurality of correlators, or a fourth of matched filters, for despreading the fourth plurality of spread-spectrum signals for generating the fourth plu despread signals. Each correlator of the fourth plurality of correlators would despread with a chipping-sequen signal having a time delay different from each time delay of each chipping-sequence signal used, respectively other correlators of the fourth plurality of correlators. Also, the chipping-sequence signal would be different frc chipping-sequence signals used with each correlator of the third plurality of correlators, each chipping-sequer signal used with each correlator of the second plurality of correlators, and each chipping-sequence signal use each correlator of the first plurality of correlators. Based on the disclosure herein, a person skilled in the art w readily know how to extend the concept to a fifth group of spread-spectrum signals, or more generally, to a pl of groups of spread-spectrum signals.

[0066] Each of the matched filters may be realized using surface-acoustic-wave (SAW) devices, digital match filters, or embodied in an application specific integrated circuit (ASIC) chip or a digital signal processor (DSP) Techniques for designing matched filters using these devices are well known in the art.

[0067] A multipath processor can single out individual paths from a group of rays. The weight for each weighti device is figured out by sets of correlators, and with a reference code it is possible to track the chipping-sequ signal in each ray.

[0068] Alternatively, a method using a multipath processor may be used for tracking a spread-spectrum signa a plurality of groups. The method comprises the steps of despreading the received signal r(t) received as the plurality of spread-spectrum signals within a first group to generate a first plurality of despread signals. The fi plurality of despread signals are then combined as a first combined-despread signal. The method would inclu despreading the received signal r(t) received as a second plurality of spread-spectrum signals within a secon to generate a second plurality of despread signals. The second plurality of despread signals would be combir a second combined-despread signal. The method includes selecting either the first combined-despread signa second combined-despread signal, as an output-despread signal.

[0069] The step of despreading the first plurality of spread-spectrum signals may include the step of correlatir matched filtering the first plurality of spread-spectrum signals, using a first plurality of correlators or a first plur matched filters, respectively. The step of despreading the second plurality of spread-spectrum signals may in the step of correlating or matched filtering the second plurality of spread-spectrum signals using a second plu correlators or a second plurality of matched filters, respectively.

[0070] The method may further include despreading a third plurality of spread-spectrum signals within a third to generate a third plurality of despread signals. The third plurality of despread signals would be combined as combined-despread signal. The selecting step would thereby include selecting one of the first combined-desp signal, the second combined-despread signal or the third combined-despread signal, as the output-despread Similarly, the step of despreading the third plurality of spread-spectrum signals may include the step of correl matched filtering the third plurality of spread-spectrum signals using a third plurality of correlators or a third pl of matched filters, respectively.

[0071] The step of despreading each of the first plurality of spread-spectrum signals would include the step o despreading with a chipping-sequence signal having a time delay different from each time delay of each chip sequence signal used to despread other spread-spectrum signals of the first plurality of spread-spectrum sigr Similarly, the step of despreading each of the second plurality of spread-spectrum signals would include the s despreading with a chipping-sequence signal having a time delay different from each time delay of each chip sequence signal used to despread other spread-spectrum signals of the second plurality of spread-spectrum Also, the step of despreading each of the second plurality of spread-spectrum signals would include the step despreading with a chipping-sequence signal having a time delay different from each time delay of each chip sequence signal used to despread other spread-spectrum signals of the first plurality of spread-spectrum sigr

[0072] In the event the method includes the step of despreading a third plurality of spread-spectrum signals, t method would include the steps of despreading with a chipping-sequence signal having a time delay different each time delay of each chipping-sequence signal used to despread other spread-spectrum signals of the thi plurality of spread-spectrum signals. Also, the time delay would be different for each chipping-sequence sign to despread spread-spectrum signals of the second plurality of spread-spectrum signals, and different from e time delay of each chipping-sequence signal used to despread spread-spectrum signals of the first plurality o spread-spectrum signals.

[0073] The method may be extended to a fourth, fifth or plurality of groups of spread-spectrum signals.

Variable Bandwidth Filter

[0074] The present invention also includes a variable-bandwidth spread-spectrum device for use with a sprea spectrum transmitter. The variable-bandwidth spread-spectrum device generates a spread-spectrum signal h spread bandwidth. The term "spread bandwidth", as used herein, denotes the bandwidth of the transmitted sp spectrum signal. The variable-bandwidth spread-spectrum device uses a chipping-sequence signal having a chipping rate which is less than the spread bandwidth. The term "chipping rate", as used herein, denotes the bandwidth of the chipping-sequence signal.

[0075] The variable-bandwidth spread-spectrum device includes first generating means, second generating n

spread-spectrum processing means, and filtering means. The spread-spectrum processing means is coupled first generating means. The second generating means is coupled between the spread-spectrum processing n and the filtering means.

[0076] The first generating means generates the chipping-sequence signal with the chipping rate. The spread spectrum processing means processes a data signal with the chipping-sequence signal to generate a spread signal. The second generating means generates an impulse signal, in response to each chip of the spread-dε signal. The filtering means filters the spectrum of each impulse signal with a bandpass equal to the spread bandwidth.

[0077] As illustratively shown in FIG. 16, the first generating means may be embodied as a chipping-sequenc generator 161, the second generating means may be embodied as an impulse generator 165, the spread-spε processing means may be embodied as an EXCLUSIVE-OR gate product device 164, or other device known those skilled in the art for mixing a data signal with a chipping-sequence signal, and the filtering means may t embodied as a filter 166.

[0078] The product device 164 is coupled to the chipping-sequence generator 161. The impulse generator 16 coupled between the product device 164 and the filter 166.

[0079] The chipping-sequence generator 161 generates the chipping-sequence signal with the chipping rate. product device 164 processes the data signal with the chipping-sequence signal, thereby generating a spreac signal as shown in FIG. 17. The impulse generator 165 generates an impulse signal, as shown in FIG. 18, in response to each chip in the spread-data signal shown in FIG. 17. Each impulse signal of FIG. 18 has an imp bandwidth. The term "impulse bandwidth", as used herein, denotes the bandwidth of the impulse signal. Whil theoretically an impulse signal has infinite bandwidth, practically, the impulse signal has a bandwidth which is greater than the spread bandwidth.

[0080] The filter 166 has a bandwidth adjusted to the spread bandwidth. Thus, the filter 166 filters a spectrum each impulse signal of the spread-data signal with the spread bandwidth. The filter 166 does this for each imp signal.

[0081] The filter 166 preferably includes a variable-bandwidth filter. The variable-bandwidth filter may be usec varying or adjusting the spread bandwidth of the spectrum for each impulse signal. Accordingly, a spread-spε signal may be designed having the bandwidth of choice, based on the bandwidth of the variable-bandwidth fil The bandwidth may be variable, or adjustable, as would be required for particular system requirements. As us this patent, a variable bandwidth is one that is able to vary according to time conditions, background signals c interference, or other requirements in a particular system. An adjustable bandwidth would be similar to a variε bandwidth, but is used to refer to a bandwidth which may be adjusted to remain at a chosen setting.

[0082] The first generating means, as shown in FIG. 19, may include a frequency-domain-chipping-sequence generator 161 and an inverse-Fourier-transform device 162. The frequency-domain-chipping-sequence genei 161 may be used to generate a frequency-domain representation of a chipping-sequence signal. The inverse Fourier-transform device 162 transforms the frequency-domain representation of the chipping-sequence sign chipping-sequence signal.

[0083] The first generating means may further include a memory 163 for storing the chipping-sequence signa

[0084] The present invention also includes a variable-bandwidth spread-spectrum method for use with a trans The method includes the steps of generating the chipping-sequence signal with the chipping rate, and spread spectrum processing a data signal with the chipping-sequence signal to generate a spread-data signal. Each the spread-spectrum signal is used to generate an impulse signal. Each impulse signal is filtered with the spr bandwidth to generate the desired bandwidth signal.

[0085] Thus, the variable-bandwidth-spread-spectrum device uses a lower chip rate, but provides a wider bar signal. The power spectral density at the output of the filter 166 of the filtered-spread-data signal s(t) is propoı to the frequency response H(f) of the filter.
PSDs(t) = k¦H(f)¦<2>
Thus, the filter 166 controls the shape of the spectrum of the filtered-spread-data signal.

[0086] The processing gain (PG) is bandwidth W of the filtered-spread-data signal divided by chip rate Rb of t filtered-spread-data signal.
PG = W/Rb
The capacity N of the filtered-spread-data signal is
N ≤ PG DIVIDED Eb/No + 1

The capacity does not depend on chip rate, but instead on bandwidth. One can achieve an upper bound on th capacity if the chip rate is greater than the bandwidth. But, if the chip rate were lower, then one can save pow consumption, i.e., use a lower clock rate of CMOS, which determines power consumption.

Adaptive Power Control System

[0087] The present invention assumes that a plurality of mobile stations operate in a cellular-communications network using spread-spectrum modulation. The cellular communications network has a plurality of geograph regions, with a multiplicity of cells within each geographical region. The size of the cells in a first geographical may differ from the size of the cells in a second geographical region. In a first geographical region, such as ar environment, the cellular architecture may have a large number of cells, each of small area, which place the corresponding base station close to each other. In a second geographical region, such as a rural environmen cellular architecture may have a smaller number of cells, each of larger area. Further, the size of the cells ma even within a specified geographic region.

[0088] A mobile station, while in the urban environment of the first geographical region, may be required to tra at a lower power level than while in the rural environment of the second geographical region. This requiremer be due to a decreased range of the mobile station from the base station. Within a particular cell, a mobile stat near the base station of the cell may be required to transmit with a power level less than that required when tl mobile station is near an outer perimeter of the cell. This adjustment in power level is necessary to ensure a constant power level is received at the base station from each mobile station.

[0089] Adaptive power control works by measuring the received signal to noise ratio (SNR) for each user and causing the user transmitted power to vary in a manner to cause all users' SNR's to be equal to a common va which will be adequate for reliable communication if the total number of users and interference is less than sy capacity. While this assumes that all users are obtaining the same service, e.g., 32 kbs voice data, it is a feat the system described that different service options are supported for requesting users. This is done by adjusti setpoint for each user independently.

[0090] There are two issues that arise when addressing the base operation of an adaptive power control syst The first is the common value obtained for SNR versus the load and its cost to the transmitters in terms of transmitted power, and the second is the stability of the system. Stability means that a perturbation of the sys from its quiescent state causes a reaction of the system to restore the quiescent condition. It is highly desirab there exist only one quiescent point because otherwise "chatter" or oscillation may occur. Stability must be addressed with any control system but, in the present case, the situation is somewhat complicated by the fact the users affect one another, and thereby cause the control variables, the transmitted power and resulting SN be dynamically coupled. The coupling is apparent when one realizes that all signals are processed by a comr AGC function which does not discriminate individual user signals from each other or from other sources.

[0091] The power control scheme of the present invention is a closed loop scheme. The system measures th correlator output power for each user and compares the measured value with a target value or setpoint. This measured power includes both the desired signal component and unwanted power or noise.

[0092] The AGC maintains the total power into each correlator at a preset level. This level does not vary as a function of APC action; that is, this role of the AGC is independent of APC. Furthermore, an increase in recei power from any user or subset of users will be "attacked" by the AGC. This is possible because the AGC time constant is smaller than the APC time constant, i.e., the AGC is faster than the APC. Since the total power av out of the AGC is fixed, an increase in the portion due to one user comes at the expense of all other users. W this may work against the apparent stability of the system, the AGC sensor, which measures the AGC control and thereby measures the total received power, causes the system to seek a quiescent state corresponding t minimum received power per user. It is desired that the transmitted power be minimized because this will min intercell interference and conserve battery power. Excess transmitter power will be dissipated within the AGC long as all users transmit excessive power.

[0093] The implementation shown in the figures is to be considered representative. In particular, the method c controlling the remote transmitter power via attenuators and variable gain amplifiers is perhaps redundant. Eit both of these means may be employed, depending upon the (dynamic) range of control required. Also, contrc be caused at either IF or RF frequencies.

[0094] For discussion purposes, a mobile station within a particular cell transmits a first spread-spectrum sign the base station transmits a second spread-spectrum signal.

[0095] In the exemplary arrangement shown in FIG. 20, a block diagram of a base station as part of a system adaptive-power control of a spread-spectrum transmitter is provided.

[0096] FIG. 20 illustrates the base station adaptive power control system with automatic gain control (AGC) m power means, comparator means, transmitter means, and an antenna. The AGC means is shown as an auto gain-control (AGC) amplifier 228, correlator means is shown as despreader 231, and power means is shown power measurement device 233. The comparator means is shown as comparator 239, the transmitter means shown as power amplifier 237 coupled to the antenna 226. Also illustrated is a delta modulator 235 coupled b comparator 239 and power amplifier 237.

[0097] The AGC amplifier 228 is coupled to the despreader 231. The power measurement device 233 is coup the despreader 231. The comparator 239 is coupled to the output of the power measurement device 233 and AGC amplifier 228. The multiplexer 234 is coupled between the comparator 239 and the power amplifier 237. delta modulator 235 is coupled between the power amplifier 237 and the multiplexer 234. The power amplifie coupled to the antenna 56.

[0098] A threshold level is used by the comparator 239 as a comparison for the received-power level measur the power measurement device 233.

[0099] For each received signal, the AGC amplifier 228 generates an AGC-output signal and an AGC-control The AGC-output signal is despread to obtain the signal of a first user using despreader 231. The despread-A output signal from the despreader 231 is combined with the AGC-control signal from the AGC amplifier 228, b combiner 241. The AGC-control signal from the AGC amplifier 228 may be offset by offset level S1 using com 242, and weighted by weighting device 243. The weighting device 243 may be an amplifier or attenuator.

[0100] The received-power level from power device 233 may be offset by offset level S2 using combiner 244, weighted by weighting device 245. The weighting device 245 may be an amplifier or attenuator. The combine combines the AGC-control signal with the received-level signal, for generating adjusted-received-power level. comparator 239 generates a comparison signal by comparing the adjusted-received-power level to the thresh level. The comparison signal may be an analog or digital data signal. The comparison signal indicates whethe mobile station is to increase or decrease its power level. If the adjusted-received-power level exceeds the thr for example, then the comparison signal sends a message to the mobile station to decrease its transmitter po the adjusted-received-power level were below the threshold, then the comparison signal sends a message to mobile station to increase its transmitter power. The comparison signal is converted to a power-command sig the delta modulator 235.

[0101] The power-command signal may be transmitted with or separate from the second spread-spectrum sig For example, a spread-spectrum signal using a first chip sequence may be considered a first spread-spectrur channel, and a spread-spectrum signal using a second chip sequence may be considered a second spread-spectrum channel. The power-command signal may be transmitted in the same spread-spectrum channel, i.e first spread-spectrum channel, as the second spread-spectrum signal, in which case the power-command sig transmitted at a different time interval from when the second spread-spectrum signal is transmitted. This form allows the mobile station to acquire synchronization with the first sequence, using the second spread-spectru signal. The power-command signal may also be transmitted in a second spread-spectrum channel which is di from the second spread-spectrum signal. In this case, the second spread-spectrum signal having the power-command signal would be acquired by the second chipping-sequence generator and second product device. power-command signal may be time division multiplexed or frequency division multiplexed with the second sp spectrum signal.

[0102] The base-correlator means is depicted in FIG. 20 as first despreader 231. The system, by way of exan may have the base-correlator means embodied as a product device, a chip-sequence generator, and a band filter. Alternatively, the base-correlator means may be realized as a matched filter such as a surface-acoustic device, or as a digital matched filter embodied in a digital signal processor. In general, the base-correlator me uses or is matched to the chip sequence of the spread-spectrum signal being received. Correlators and matc filters for despreading a spread-spectrum signal are well known in the art.

[0103] Typically, the AGC circuit 228 is coupled to a low noise amplifier 227, through an isolator 225 to the an 226. In FIG. 20 a plurality of despreaders, despreader 229 through despreader 231, are shown for despreadi plurality of spread-spectrum channels which may be received from a plurality of mobile stations. Similarly, the of each despreader 229 through despreader 231 is coupled to a plurality of demodulators, illustrated as demc 230 through demodulator 232, respectively, for demodulating data from the despread AGC-output signal. Accordingly, a plurality of data outputs are available at the base station.

[0104] For a particular spread-spectrum channel, the first despreader 231 is shown coupled to power device :

multiplexer 234. The power device 233 typically is a power-measurement circuit which processes the despre AGC-output signal as a received-power level. The power device 233 might include an analog-to-digital conve circuit for outputting a digital received-power level. The comparator means, embodied as comparator circuit 2 compares the processed received-power level to a threshold. The multiplexer 234 is coupled to the output of power device 233 through the comparator circuit 239. The multiplexer 234 may insert appropriate framing bits required.

[0105] The transmitter means may be embodied as a quadrature phase shift keying (QPSK) modulator or a d modulator 235 coupled to a power amplifier 237. In FIG. 20, the input to the delta modulator 235 typically wou the power-command signal from the power device 233 multiplexed with data from the k<th> channel. A plural spread spectrum channels would have their data and appropriate power-command signals combined by com 236 and amplified by power amplifier 237. The output of the power amplifier 237 is coupled through the isolat to the antenna 226.

[0106] The power command signal is transmitted periodically. The period T might be chosen to be 250 micros in order to ensure a low root mean square error as well as a low peak error between the instantaneous receiv signal and the constant desired signal.

[0107] A mobile station is illustratively shown in FIG. 21. The mobile-despreading means is illustrated as des 334 and variable-gain means is illustrated as a variable-gain device 341. The variable-gain device 341 is cou between the transmitter 342 and through isolator 336 to antenna 335. The despreader 334 is coupled to the i 336 and to demultiplexer 339. The output of the despreader 334 is also coupled to a demodulator 340. The despreader 334 may be embodied as an appropriate correlator, or matched filter, for despreading the k<th> c Additional circuitry may be used, such as radio frequency (RF) amplifiers and filters, or intermediate frequenc amplifiers and filters, as is well known in the art.

[0108] A received second spread-spectrum signal at antenna 335 passes through isolator 336 to despreader The despreader 334 is matched to the chip sequence of the desired spread-spectrum channel. The output of despreader 334 passes through the demodulator 340 for demodulating the data from the desired spread-spe channel. Additionally, the demultiplexer 339 demultiplexes the power-command signal from the despread sig outputted from despreader 334. The power-command signal drives the variable-gain device 341.

[0109] A decision device 345 and accumulator 346 may be coupled between the demultiplexer 339 and the v gain device 341. A step-size-algorithm device 344 is coupled to the output of the decision device 345 and to t accumulator 346.

[0110] The step-size-algorithm device 344 stores an algorithm for adjusting the power level of the variable ga device 341. A nonlinear algorithm that might be used is shown in FIG. 22. FIG. 23 compares a nonlinear algo with a linear step size algorithm.

[0111] The power-command signal from the demultiplexer 339 causes the decision device 345 to increase or decrease the power level of the variable gain device 341, based on the threshold of the step size algorithm sh FIG. 23. The accumulator tracks previous power levels as a means for assessing the necessary adjustments step size of the power level pursuant to the algorithm as shown in FIG. 23.

[0112] The variable-gain device 341 may be embodied as a variable-gain amplifier, a variable-gain attenuato device which performs the same function as the variable-gain device 341 as described herein. The variable-g device 341 increases or decreases the power level of the remote station transmitter, based on the power-con signal.

[0113] As illustratively shown in FIG. 20, a block diagram of a power measurement circuit includes interferenc rejection for use with the base station. As shown in FIG. 20, the AGC amplifier 228 is connected to the despr 231, and the output of the despreader 231 is connected to the power measurement circuit 233. Additionally, t AGC amplifier 228 is connected to the combiner 236 through the comparator 239.

[0114] A received signal includes a first spread-spectrum signal with power PC and the other input signals wh considered to be interfering signals with power PJ at the input to the AGC amplifier 228 of FIG. 20. The interf signal may come from one or more nondesirable signals, noise, multipath signals, and any other source whic serve as an interfering signal to the first spread-spectrum signal. The received signal is normalized by the AG amplifier 228. Thus, by way of example, the AGC amplifier 228 can have the power output, PC + PJ = 1. The normalized received signal is despread by the despreader 231 to receive a particular mobile user's signal. Th chipping-sequence generator of despreader 231 generates a chip-sequence signal using the same chip sequ as used by the first spread-spectrum signal. Alternatively, the matched filter, if used, of despreader 231 may impulse response matched to the same chip sequence as used by the first spread-spectrum signal. The outp

the despreader 231 is the normalized power of the first spread-spectrum signal plus the normalized power of interfering signal divided by the processing gain, PG, of the spread-spectrum system. The power measureme circuit 233 generates a received-power level of the first spread-spectrum signal. The comparator 239 process despread-received signal with the AGC-control signal and outputs the power-control signal of the first spread-spectrum signal. The power level of the interfering signal is reduced by the processing gain, PG.

[0115] The comparator 239 processes the AGC-control signal with the despread, normalized received signal multiplying the two signals together, or by logarithmically processing the AGC-control signal with the desprea received signal. In the latter case, the logarithm is taken of the power of the received signal, PC + PJ, and the logarithm is taken of the despread, normalized received signal. The two logarithms are added together to pro the received-power level.

[0116] For the present invention to work effectively, the despread signal must be kept nearly constant, indepe of variations in the other signals or of obstructions. A preferred implementation to accomplish this end is show the circuitry of FIG. 20. FIG. 20 depicts a means for determining at the base station the power of the first spre spectrum signal when the received signal includes multiple signals and noise. If the circuitry of FIG. 20 were r used, then it is possible that the interfering signal, which may include noise, multipath signals, and other unde signals, may raise the power level measured at the input to the receiver of the base station, thereby suppress first spread spectrum signal. The undesirable power level measured may cause the remote station to transmi power than required, increasing the amount of power received at the base station.

[0117] As noted earlier, the APC system is a closed loop system. The APC loop operates by generating comr to increase or decrease the transmitter power at the update rate. This is actually quantization process that is limit the amount of information that must be fed back to the remote transmitter. The amount of increase or de may be fixed in advance or it may adapt in response to the characteristics of the channel as measured locally remote terminal, the terminal being controlled. In particular, the remote terminal may examine the sequence c commands received by it. A long sequence of increase commands, for example, implies that the step size ma increased. A typical scheme increases the step size by a fixed amount or a fixed percentage whenever two successive bits are the same. For example, the step size may be increased by 50% if two bits in a row are th and decreased by 50% if they differ. This is a fairly gross change in the step size, and is intended to be adapt local, or immediate in time, variations in the required transmitted power. This process results in a large variati the step size with time.

[0118] An adaptive step size algorithm may also be considered in a different context. Specifically, the step siz be considered to be nearly constant or not responding to localized variations in demanded transmitted power, the value may be automatically adjusted based on the global characteristics of the channel induced control ac Thus, in a nearly static environment one should use a small constant step size while in a mobile environment step size should be larger.

[0119] Adjustment of the power level of the remote station transmitter may be effected either linearly or nonlin The following algorithm will cause the step size to settle at a nearly optimum constant value. The receiver exa successive APC bits and increases the step size by the factor (1+x) if they agree and decreases the step size factor (1+x) if they disagree. Here the parameter x is small (x = 0.01, for example.) While this procedure will n allow local adaptation (because x is small), it will result in an adaptation to global conditions. Specifically, if th transmitted APC bit stream exhibits a tendency toward successive bits in agreement (i.e., runs of 1's or 0's ar evident) it implies that the system is not following the changes in channel conditions (i.e., the system is slow r limited) and the step size should be increased. On the other hand, if successive bits tend to be opposite, the s is "hunting" for a value between two values that are excessively far apart. The statistics one expects to obser optimal are intermediate to these extremes. That is, the APC bit stream should appear equally likely to contai patterns (0,0), (0,1), (1,0), and (1,1) in any pair of successive bits. The above algorithm drives the system bel toward this.

[0120] The above algorithm (global adaptation) works particularly well when the system employs a high updat relative to the dynamics of the channel.

[0121] As illustrated in FIG. 23, to increase the power level using linear adjustment, for example, the transmitt power is increased in regular increments of one volt, or other unit as instructed by the base station, until the p level received at the base station is sufficiently strong. Linear adjustment may be time consuming if the powe adjustment necessary were substantial.

[0122] As shown in FIG. 22, to increase the power using nonlinear adjustment, the transmitter voltage may be increased, by way of example, geometrically until the transmitted power is in excess of the desired level. Trar power may be then reduced geometrically until transmitted power is below the desired level. A preferred appr to increase the step size voltage by a factor of 1.5 and to decrease the step size by a factor of 0.5. Other non

algorithms may be used. As shown in FIG. 23, this process is repeated, with diminishing margins of error in b excess and insufficiency of desired power, until the desired signal level has been obtained. Nonlinear adjustn provides a significantly faster rise and fall time than does linear adjustment, and may be preferable if power n adjusted significantly.

[0123] The system determines the error state (APC bit) every T sections, 1/T being the update rate of the con The update rate may vary from 100 Hz, which is low, to 100 kHz, which is quite high. The opportunity to meas error state of the system arises with each reception of a new symbol. Thus, the update rate may be equal to t symbol rate. If such an update rate is not supported, it is beneficial to make use of the available error measur by combining them (or averaging them) between updates. This minimizes the chance of causing a power adjı in the wrong direction which can occur because of noise in the error signals themselves.

[0124] The choice of update rate depends on factors other than APC operation, namely, the amount of capac method of allocating capacity to the transport of the APC bits over the channel. In general, a faster update wil produce superior performance, even if the increased update rate is obtained by permitting the APC bits to be received in error occasionally. Elaborating, a 1 kHz update rate with no channel induced errors will perform le effectively than a 100 kHz update rate at a 25% rate of errors. This is because of the self correcting behavior control loop. A faster update rate eliminates the latency of control which is a key performance limiting phenon

[0125] A spread spectrum base station receives all incoming signals simultaneously. Thus, if a signal were re at a higher power level than the others, then that signal's receiver has a higher signal-to-noise ratio and there lower bit error rate. The base station ensures that each mobile station transmits at the correct power level by the remote, every 500 microseconds, whether to increase or to decrease the mobile station's power.

[0126] FIG. 24 shows a typical fading signal which is received at the base station along with ten other indepeı fading signals and thermal noise having the same power as one of the signals. Note that the fade duration is milliseconds which corresponds to vehicular speed exceeding 60 miles per hour. FIGS. 25-26 illustrate the re obtained when using a particular adaptive power control algorithm. In this case, whenever the received signal changes power, the base station informs the remote and the remote varies its power by +/-1 dB. FIG. 25 shov adaptive power control signal at the remote station. FIG. 26 shows the received power at the base station. Nc the adaptive power control track the deep fades and as a result 9 dB fades resulted. This reduced power leve resulted in a bit error rate of 1.4 x 10<-2>.

[0127] For the same fade of FIG. 24, assume a different adaptive power control algorithm is employed as sho FIGS. 27-28. In this case the control voltage results in the remote unit changing its power by a factor of 1.5 in same direction, or by a factor of 0.5 in the opposite direction. In this particular implementation the minimum st was 0.25 dB and the maximum step size was 4 dB. Note that the error is usually limited to +/-2 dB with occas decreases in power by 5 dB to 6 dB resulting in a BER APPROX 8 x 10<-4>, a significant improvement comp the previous algorithm. The use of interleaving and forward error correcting codes usually can correct any err resulting from the rarely observed power dips.

[0128] In operation, a mobile station in a cell may transmit the first spread-spectrum signal on a continuous ba on a repetitive periodic basis. The base station within the cell receives the first spread-spectrum signal. The r first spread-spectrum signal is acquired and despread with the chip-sequence signal from chip-sequence gen and product device. The despread first spread-spectrum signal is filtered through bandpass filter. The base st detects the despread first spread-spectrum signal using envelope detector, and measures or determines the received-power level of the first spread-spectrum signal. The base station generates the power-command sig from the received-power level.

[0129] The present invention also includes a method for automatic-power control of a spread-spectrum transr for a mobile station operating in a cellular-communications network using spread-spectrum modulation, with t mobile station transmitting a first spread-spectrum signal. In use, the method includes the step of receiving a received signal, generating an AGC-output signal, despreading the AGC-output signal, processing the despre AGC-output signal to generate a received-power level, generating a power-command signal, transmitting the command signal as a second spread-spectrum signal, despreading the power-command signal from the secc spread-spectrum signal as a power-adjust signal, and adjusting a power level of the first spread-spectrum sig

[0130] The received signal includes the first spread-spectrum signal and an interfering signal and is received base station. The AGC-output signal is generated at the base station and despread as a despread AGC-outp signal. The despread AGC-output signal is processed at the base station to generate a received-power level.

[0131] The received-power level is compared to a threshold, with the comparison used to generate a power-command signal. If the received-power level were greater than the threshold, the power-command signal wou command the mobile station to reduce transmitter power. If the received-power level were less than the thres

the power-command signal would command the mobile station to increase transmitter power.

[0132] The power-command signal is transmitted from the base station to the mobile station as a second spre spectrum signal. Responsive to receiving the second spread-spectrum signal, the mobile station despreads tl power-command signal as a power-adjust signal. Depending on whether the power-command signal commar the mobile station to increase or decrease transmitter power, the mobile station, responsive to the power adju signal, increases or decreases the transmitter-power level of the first spread-spectrum signal, respectively.

[0133] The method may additionally include generating from a received signal an AGC-output signal, and despreading the AGC-output signal. The received signal includes the first spread-spectrum signal and an inte signal. The received signal is processed with the despread AGC-output signal to generate a received-power l The method then generates a comparison signal by comparing the received-power level to the threshold leve transmitting a second spread-spectrum signal, the method adjusts a transmitter-power level of the first spreac spectrum signal from the transmitter using the power-adjust signal.

[0134] It will be apparent to those skilled in the art that various modifications can be made to the spread-spec system and method of the instant invention without departing from the scope or spirit of the invention, and it is intended that the present invention cover modifications and variations of the spread-spectrum system and me provided they come within the scope of the appended claims and their equivalents.

Spread-spectrum system and meth d

Claims of **EP1041727**

1. A multipath processor for tracking a spread-spectrum signal within a plurality of groups of spread-spectrum signals, each group having a plurality of spread-spectrum signals, said multipath processor comprising:

first means for despreading a first plurality of spread-spectrum signals within a first group, to generate, respec a first plurality of despread signals;
first means, coupled to said first despreading means, for combining the first plurality of despread signals as a combined-despread signal;
second means for despreading a second plurality of spread-spectrum signals within a second group, to gene respectively, a second plurality of despread signals;
second means, coupled to said second despreading means, for combining the second plurality of despread s as a second combined-despread signal; and
means, coupled to said first combining means and to said second combining means, for selecting one of the 1 combined-despread signal and the second combined-despread signal, as an output-despread signal.

2. The multipath processor as set forth in claim 1, wherein:

said first despreading means includes a first plurality of correlators for despreading, respectively, the first plur spread-spectrum signals, thereby generating the first plurality of despread signals; and
said second despreading means includes a second plurality of correlators for despreading, respectively, the s plurality of spread-spectrum signals, thereby generating the second plurality of despread signals.

3. The multipath processor as set forth in claim 2, wherein:

each correlator of said first plurality of correlators despreads with a chipping-sequence signal having a time d different from each time delay of each chipping-sequence signal used with other correlators of said first plural correlators; and
each correlator of said second plurality of correlators despreads with a chipping-sequence signal having a tim different from each time delay of each chipping-sequence signal used with other correlators of said second pl of correlators, and having the time delay different from each time delay of each chipping-sequence signal use other correlators of said first plurality of correlators.

4. The multipath processor as set forth in claim 1, wherein:

said first despreading means includes a first plurality of matched filters for despreading, respectively, the first plurality of spread-spectrum signals, thereby generating the first plurality of despread signals; and
said second despreading means includes a second plurality of matched filters for despreading, respectively, t second plurality of spread-spectrum signals, thereby generating the second plurality of despread signals.

5. The multipath processor as set forth in claim 1, further comprising:

third means for despreading a third plurality of spread-spectrum signals within a third group, to generate, respectively, a third plurality of despread signals;
third means, coupled to said third despreading means, for combining the third plurality of despread signals as combined-despread signal; and
wherein said selecting means, coupled to said third combining means, selects one of the first combined-desp signal, the second combined-despread signal and the third combined-despread signal, as the output-desprea signal.

6. The multipath processor as set forth in claim 5, wherein:

said first despreading means includes a first plurality of correlators for despreading, respectively, the first plur spread-spectrum signals, thereby generating the first plurality of despread signals;

said second despreading means includes a second plurality of correlators for despreading, respectively, the s plurality of spread-spectrum signals, thereby generating the second plurality of despread signals; and
said third despreading means includes a third plurality of correlators for despreading the third plurality of spre spectrum signals, respectively, thereby generating the third plurality of spread-spectrum signals.

7. The multipath processor as set forth in claim 6, wherein:

each correlator of said first plurality of correlators despreads with a chipping-sequence signal having a time d different from each time delay of each chipping-sequence signal used with other correlators of said first plural correlators;
each correlator of said second plurality of correlators despreads with a chipping-sequence signal having a tim different from each time delay of each chipping-sequence signal used with other correlators of said second pl of correlators, and having the time delay different from each time delay of each chipping-sequence signal use other correlators of said first plurality of correlators; and
each correlator of said third plurality of correlators despreads with a chipping-sequence signal having a time c different from each time delay of each chipping-sequence signal used with other correlators of said third plura correlators, having the time delay different from each time delay of each chipping-sequence signal used with correlators of said second plurality of correlators, and having the time delay different from each time delay of chipping-sequence signal used with other correlators of said first plurality of correlators.

8. The multipath processor as set forth in claim 5, wherein:

said first despreading means includes a first plurality of matched filters for despreading, respectively, the first plurality of spread-spectrum signals, thereby generating the first plurality of despread signals;
said second despreading means includes a second plurality of matched filters for despreading, respectively, t second plurality of spread-spectrum signals, thereby generating the second plurality of despread signals; and
said third despreading means includes a third plurality of matched filters for despreading, respectively, the thi plurality of spread-spectrum signals, thereby generating the third plurality of despread signals.

9. The multipath processor as set forth in claim 5, further comprising:

fourth means for despreading a fourth plurality of spread-spectrum signals within a fourth group, to generate, respectively, a fourth plurality of despread signals;
fourth means, coupled to said fourth despreading means, for combining the fourth plurality of despread signal fourth combined-despread signal; and
wherein said selecting means, coupled to said fourth combining means, selects one of the first combined-des signal, the second combined-despread signal, the third combined-despread signal and the fourth combined-despread signal, as the output-despread signal.

10. The multipath processor as set forth in claim 9, wherein:

said first despreading means includes a first plurality of correlators for despreading, respectively, the first plur spread-spectrum signals, thereby generating the first plurality of despread signals;
said second despreading means including a second plurality of correlators for despreading, respectively, the plurality of spread-spectrum signals, thereby generating the second plurality of despread signals;
said third despreading means includes a third plurality of correlators for despreading the third plurality of spre spectrum signals, respectively, for generating the third plurality of despread signals; and
said fourth despreading means includes a fourth plurality of correlators for despreading the fourth plurality of spectrum signals, respectively, for generating the fourth plurality of despread signals.

11. The multipath processor as set forth in claim 10, wherein:

each correlator of said first plurality of correlators despreads with a chipping-sequence signal having a time d different from each time delay of each chipping-sequence signal used with other correlators of said first plural correlators;
each correlator of said second plurality of correlators despreads with a chipping-sequence signal having a tim different from each time delay of each chipping-sequence signal used with other correlators of said second pl of correlators, and having the time delay different from each time delay of each chipping-sequence signal use other correlators of said first plurality of correlators;

each correlator of said third plurality of correlators despreads with a chipping-sequence signal having the time different from each time delay of each chipping-sequence signal used with other correlators of said third plura correlators, having the time delay different from each time delay of each chipping-sequence signal used with correlators of said second plurality of correlators, and having the time delay different from each time delay of chipping-sequence signal used with other correlators of said first plurality of correlators; and
each correlator of said fourth plurality of correlators despreads with a chipping-sequence signal having the tin delay different from each time delay of each chipping-sequence signal used with other correlators of said four plurality of correlators, having the time delay different from each time delay of each chipping-sequence signal with other correlators of said third plurality of correlators, having the time delay different from each time delay each chipping-sequence signal used with other correlators of said second plurality of correlators, and having time delay different from each time delay of each chipping-sequence signal used with other correlators of saic plurality of correlators.

12. The multipath processor as set forth in claim 9, wherein:

said first despreading means includes a first plurality of matched filters for despreading the first plurality of spi spectrum signals, thereby generating the first plurality of despread signals;
said second despreading means includes a second plurality of matched filters for despreading the second plu spread-spectrum signals, thereby generating the second plurality of despread signals;
said third despreading means includes a third plurality of matched filters for despreading, respectively, the thi plurality of spread-spectrum signals, thereby generating the third plurality of despread signals; and
said fourth despreading means includes a fourth plurality of matched filters for despreading, respectively, the plurality of spread-spectrum signals, thereby generating the fourth plurality of despread signals.

13. A method using a multipath processor for tracking a spread-spectrum signal within a plurality of groups of spread-spectrum signals, each group having a plurality of spread-spectrum signals, comprising the steps of:

despreading a first plurality of spread-spectrum signals within a first group, to generate, respectively, a first pl of despread signals;
combining the first plurality of despread signals as a first combined-despread signal;
despreading a second plurality of spread-spectrum signals within a second group, to generate, respectively, a second plurality of despread signals;
combining the second plurality of despread signals, as a second combined-despread signal; and
selecting one of the first combined-despread signal and the second combined-despread signal, as an output-despread signal.

14. The method as set forth in claim 13, wherein:

the step of despreading the first plurality of spread-spectrum signal includes the step of decorrelating, respect the first plurality of spread-spectrum signals, thereby generating the first plurality of despread signals; and
the step of despreading the second plurality of spread-spectrum signal includes the step of decorrelating, respectively, the second plurality of spread-spectrum signals, thereby generating the second plurality of desp signals.

15. The method as set forth in claim 13, wherein:

the step of despreading each of the first plurality of spread-spectrum signals includes the step of despreading chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sign to despread other spread-spectrum signals of the first plurality of spread-spectrum signals; and
the step of despreading each of the second plurality of spread-spectrum signals includes the step of despreac with a chipping-sequence signal having a time delay different from each time delay of each chipping-sequenc signal used to despread other spread-spectrum signals of the second plurality of spread-spectrum signals, ar having the time delay different from each time delay of each chipping-sequence signal used to despread eacl spread-spectrum signal of the first plurality of spread-spectrum signals.

16. The method as set forth in claim 13, wherein:

the step of despreading the first plurality of spread-spectrum signals includes the step of filtering the first plura spread-spectrum signals, thereby generating the first plurality of despread signals; and

the step of despreading the second plurality of spread-spectrum signals includes the step of filtering the seco plurality of spread-spectrum signals, thereby generating the second plurality of despread signals.

17. The method as set forth in claim 13, further comprising the steps of:

despreading a third plurality of spread-spectrum signals within a third group, to generate, respectively, a third plurality of despread signals;
combining the third plurality of despread signals as a third combined-despread signal; and
the step of selecting includes the step of selecting one of the first combined-despread signal, the second com despread signal and the third combined-despread signal, as the output-despread signal.

18. The method as set forth in claim 17, wherein:

the step of despreading the first plurality of spread-spectrum signals includes the step of decorrelating, respe the first plurality of spread-spectrum signals, thereby generating the first plurality of despread signals;
the step of despreading the second plurality of spread-spectrum signals includes the step of decorrelating, respectively, the second plurality of spread-spectrum signals, thereby generating the second plurality of desp signals; and
the step of despreading the third plurality of spread-spectrum signals includes the step of decorrelating, respe the third plurality of spread-spectrum signals, thereby generating the third plurality of despread signals.

19. The method as set forth in claim 17, wherein:

the step of despreading each of the first plurality of spread-spectrum signals includes the step of despreading chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sign to despread other spread-spectrum signals of the first plurality of spread-spectrum signals;
the step of despreading each of the second plurality of spread-spectrum signals includes the step of despreac with a chipping-sequence signal having a time delay different from each time delay of each chipping-sequenc signal used to despread other spread-spectrum signals of the second plurality of spread-spectrum signals, ar having the time delay different from each time delay of each chipping-sequence signal used to despread spre spectrum signals of the first plurality of spread-spectrum signals; and
the step of despreading each of the third plurality of spread-spectrum signals includes the step of despreadin chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sign to despread other spread-spectrum signals of the third plurality of spread-spectrum signals, having a time del different from each time delay of each chipping-sequence signal used to despread spread-spectrum signals c second plurality of spread-spectrum signals, and having the time delay different from each time delay of each chipping-sequence signal used to despread spread-spectrum signals of the first plurality of spread-spectrum

20. The method processor as set forth in claim 17, wherein:

the step of despreading the first plurality of spread-spectrum signals includes the step of matched filtering the plurality of spread-spectrum signals, thereby generating the first plurality of despread signals;
the step of despreading the second plurality of spread-spectrum signals includes the step of matched filtering second plurality of spread-spectrum signals, thereby generating the second plurality of despread signals; and
the step of despreading the third plurality of spread-spectrum signals includes the step of matched filtering th plurality of spread-spectrum signals, thereby generating the third plurality os despread signals.

21. The method as set forth in claim 17, further comprising the steps of:

despreading a fourth plurality of spread-spectrum signals within a fourth group, to generate, respectively, a fo plurality of despread signals;
combining the fourth plurality of despread signals as a fourth combined-despread signal; and
the step of selecting includes the step of selecting one of the first combined-despread signal, the second com despread signal, the third combined-despread signal and the fourth combined-despread signal, as the output-despread signal.

22. The method as set forth in claim 21, wherein:

the step of despreading the first plurality of spread-spectrum signals includes the step of decorrelating, respe(the first plurality of spread-spectrum signals, thereby generating the first plurality of despread signals;
the step of despreading the second plurality of spread-spectrum signals includes the step of decorrelating the second plurality of spread-spectrum signals, thereby generating the second plurality of despread signals;
the step of despreading the third plurality of spread-spectrum signals includes the step of decorrelating the thi plurality of spread-spectrum signals, thereby generating the third plurality of despread signals; and
the step of despreading the fourth plurality of spread-spectrum signals includes the step of decorrelating the f plurality of spread-spectrum signals, thereby generating the fourth plurality of despread signals.

23. The method as set forth in claim 21, wherein:

the step of despreading each of the first plurality of spread-spectrum signals includes the step of despreading chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sign: to despread other spread-spectrum signals of the first plurality of spread-spectrum signals;
the step of despreading each of the second plurality of spread-spectrum signals includes the step of desprea(with a chipping-sequence signal having a time delay different from each time delay of each chipping-sequenc signal used to despread other spread-spectrum signals of the second plurality of spread-spectrum signals, ar having the time delay different from each time delay of each chipping-sequence signal used to despread othe spread-spectrum signals of the first plurality of spread-spectrum signals;
the step of despreading each of the third plurality of spread-spectrum signals includes the step of despreadin(chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sign: to despread other spread-spectrum signals of the third plurality of spread-spectrum signals, having a time del different from each time delay of each chipping-sequence used to despread other spread-spectrum signals o1 second plurality of spread-spectrum signals, and having the time delay different from each time delay of each chipping-sequence signal used to despread spread-spectrum signals of the first plurality of spread-spectrum : and
the step of despreading each of the fourth plurality of spread-spectrum signals includes the step of despreadi a chipping-sequence signal having a time delay different from each time delay of each chipping-sequence sig used to despread other spread-spectrum signals of the fourth plurality of spread-spectrum signals, having a ti delay different from each time delay of each chipping-sequence signal used to despread spread-spectrum sig the third plurality of spread-spectrum signals, having a time delay different from each time delay of each chip| sequence used to despread other spread-spectrum signals of the second plurality of spread-spectrum signals having the time delay different from each time delay of each chipping-sequence signal used to despread spre spectrum signals of the first plurality of spread-spectrum signals.

24. The method as set forth in claim 21, wherein:

the step of despreading the first plurality of spread-spectrum signals includes the step of matched filtering the plurality of spread-spectrum signals, thereby generating the first plurality of despread signals;
the step of despreading the second plurality of spread-spectrum signals includes the step of matched filtering second plurality of spread-spectrum signals, thereby generating the second plurality of despread signals;
the step of despreading the third plurality of spread-spectrum signals includes the step of matched filtering th(plurality of spread-spectrum signals, thereby generating the third plurality of despread signals; and
the step of despreading the fourth plurality of spread-spectrum signals includes the step of matched filtering tl fourth plurality of spread-spectrum signals, thereby generating the fourth plurality of despread signals.

FIG. 1

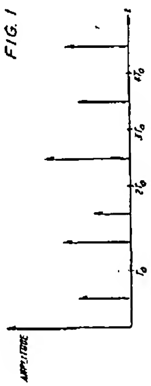
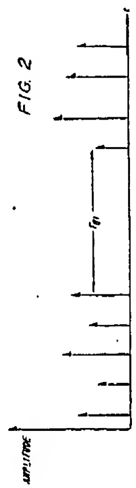


FIG. 2



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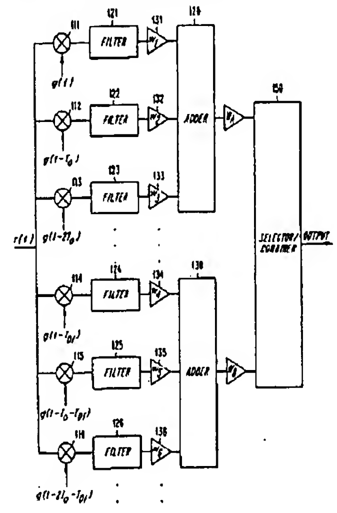

FIG. 3

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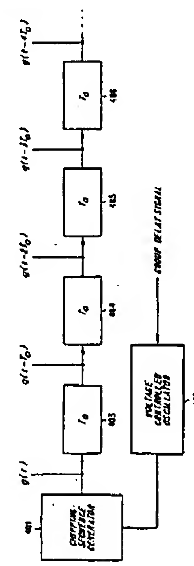
FIG. 4



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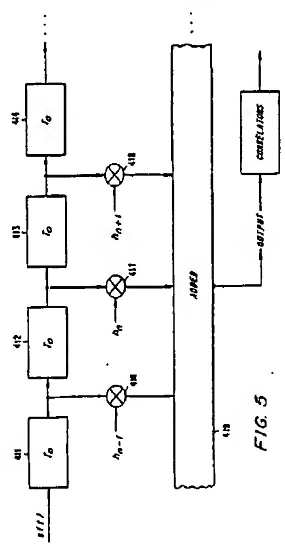

FIG. 5

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FIG. 6

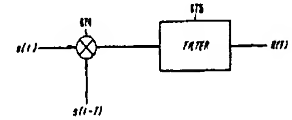

FIG. 7

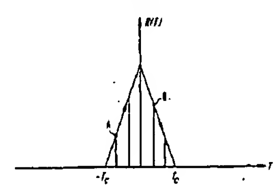

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FIG. 8